The Effect of Chloride and Orthophosphate on the Release on Iron from a Drinking Water Distribution System Pipe

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Iron Release/Iron Corrosion

- Particle formation
- Discolored water
- Sink for trace contaminants
- Staining of fixtures, clothing
- Metallic tasting water
- Flow restriction
- Oxidant demand
- Biofilm

Discussion

Corrosion is Different from Iron Release

Corrosion of iron is the conversion of "metallic iron" to an oxidized form, either soluble or an oxidized scale.

- $Fe \rightarrow Fe^{2+} + 2e^-$
- Usually measured as weight loss from metallic iron

Iron release is the transport of iron, in soluble form or as a particle, from corrosion scale or metal to bulk water.

- Cumulative effect of corrosion, hydraulic scouring and dissolution of corrosion scales.
- Usually measured as concentration of iron in bulk water

Study Objectives

Examine the effect of chloride and orthophosphate on the release of iron from an old cast iron pipe section

Chloride and Orthophosphate

Chloride

- Pitting corrosion
- Fluctuating and changing water quality

Orthophosphate

- Lead and copper corrosion control
- Iron/red water control ??

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Iron Pipe Studies

Iron Release and Particle Properties

90 year old cast iron pipe section from CWW

Experimental

Protocol

- 90 year old cast iron pipe section (4" diameter)
- Sample from center of pipe after 23.5 hours stagnation (72 hrs)
- Measure REDOX, pH, DO, iron, color, NTU, metals (ICAP)
- Slowly fill with Cincinnati tap water from bottom (rate 50 ml/min, 2-3 volumes)
  - NaCl or Na_3PO_4
- Glass cover

Experimental

Water Chemistry

Calcium	32 mg/L
Magnesium	9 mg/L
Sodium	16 mg/L
Potassium	3 mg/L
SO_4	65 mg/L
SiO_2	5 mg/L
pH	8.65
Cl	12 mg/L

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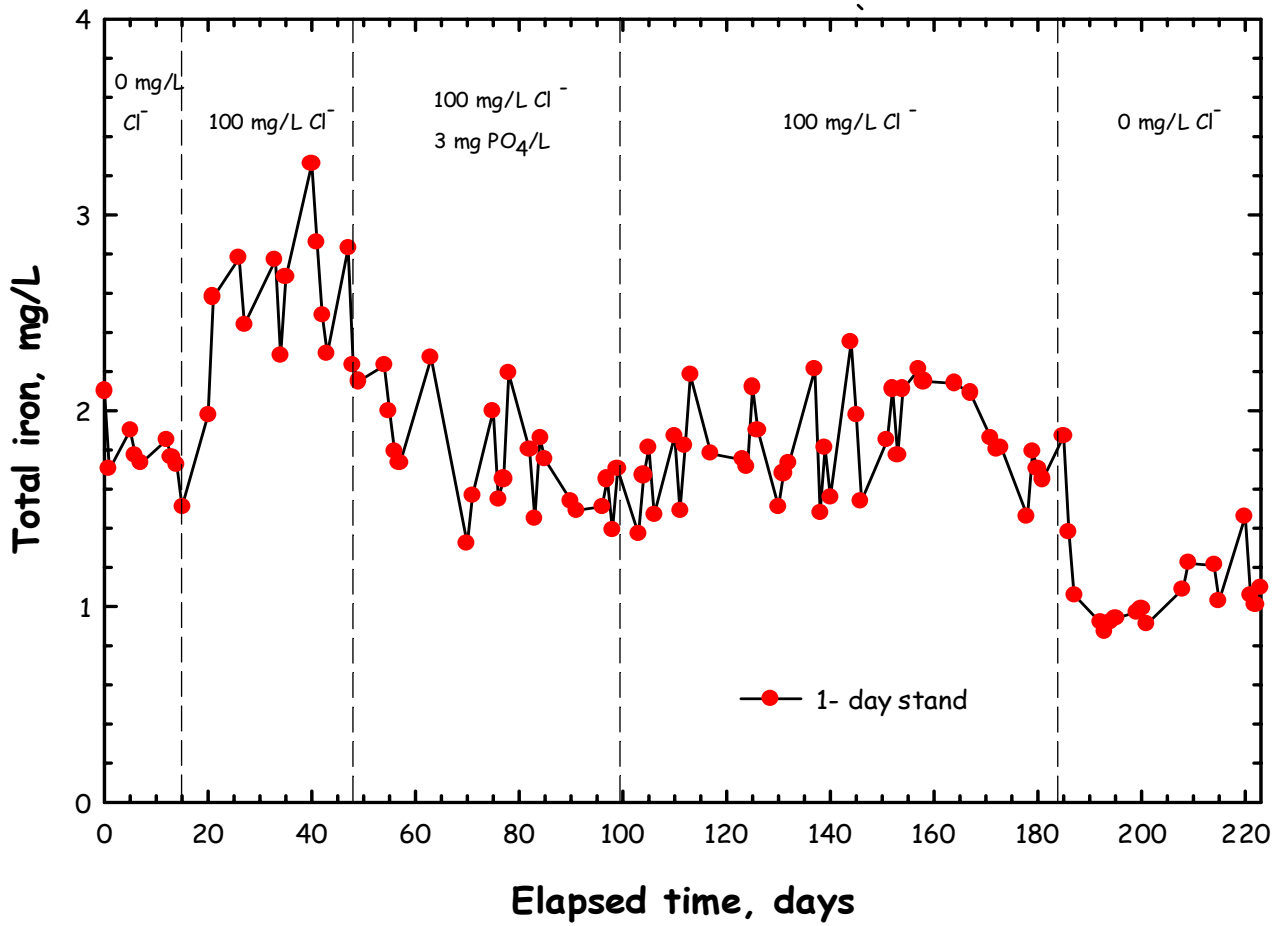
The Effect of Chloride and Phosphate on Iron Release



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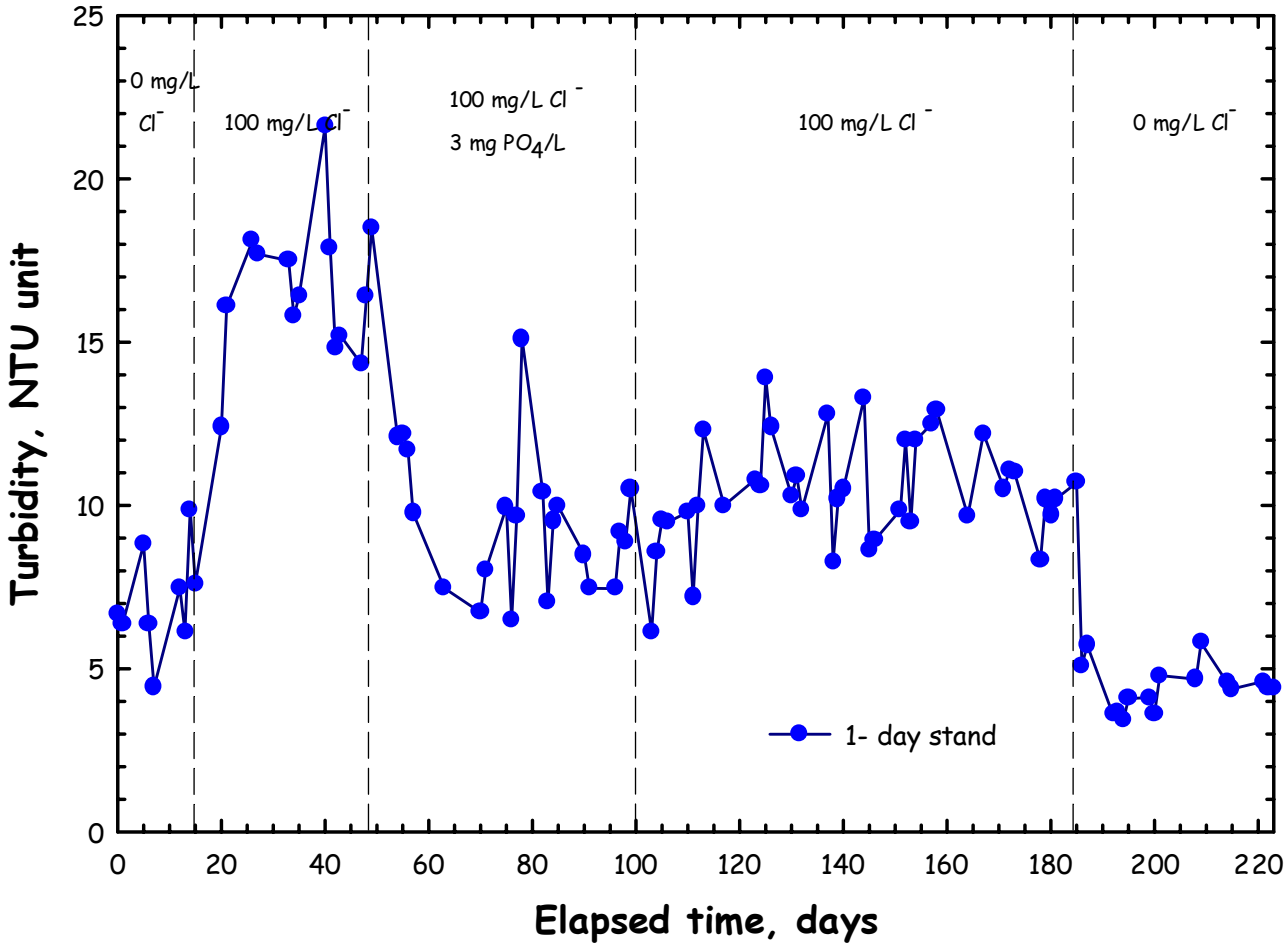
The Effect of Chloride and Phosphate on Turbidity



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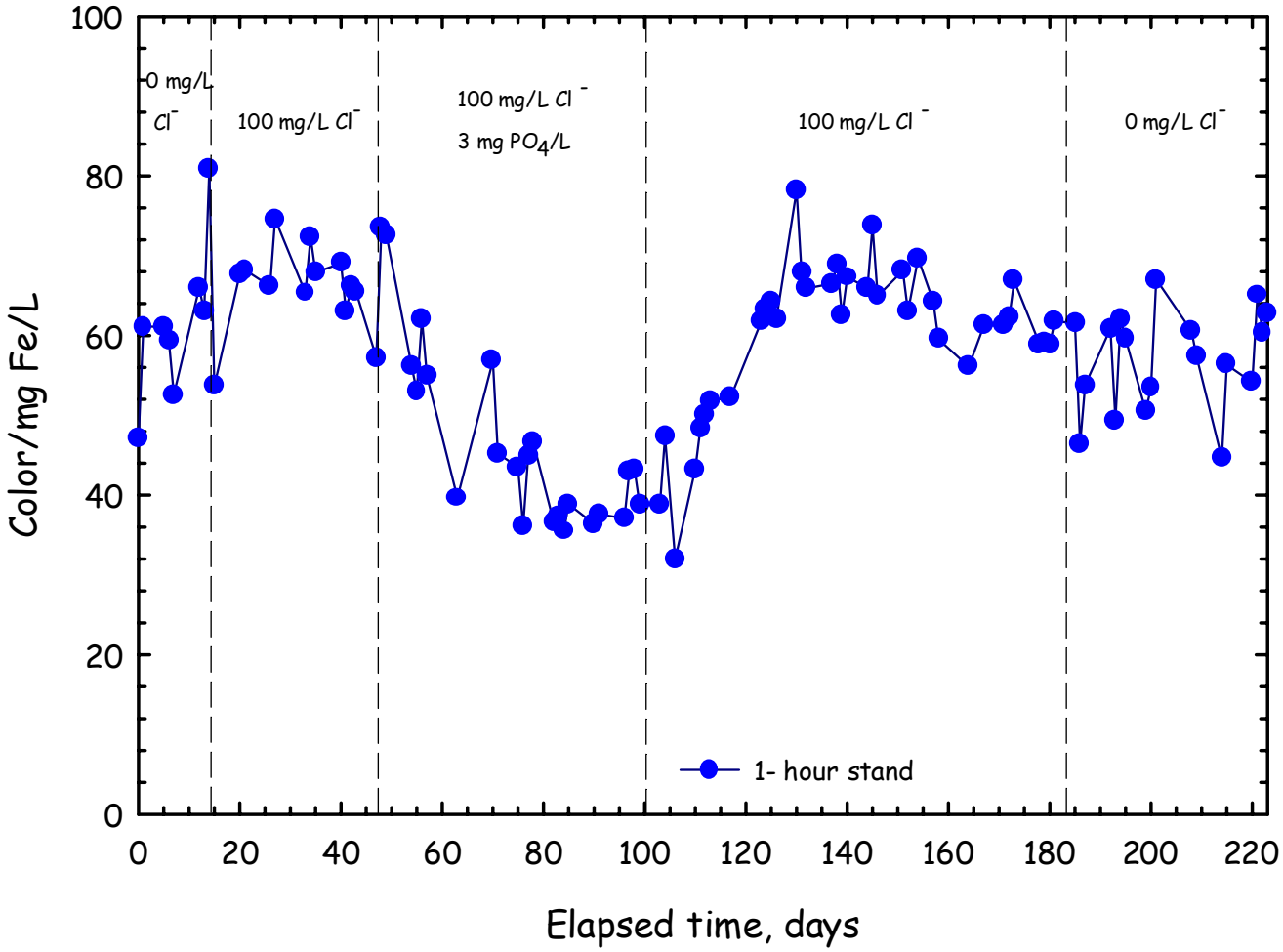
The Effect of Chloride and Phosphate on Apparent Color



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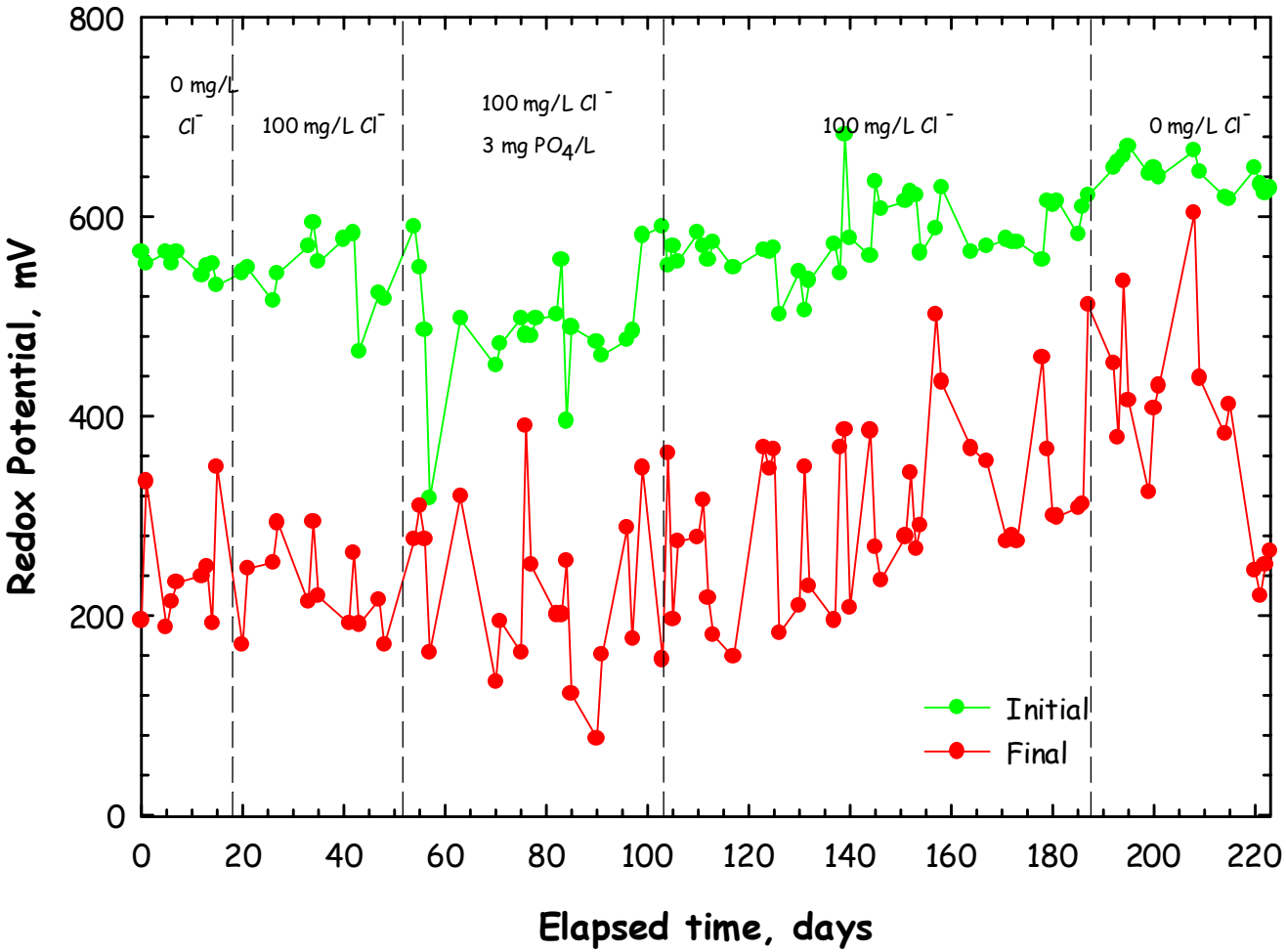
The Effect of Chloride and Phosphate on Redox Potential



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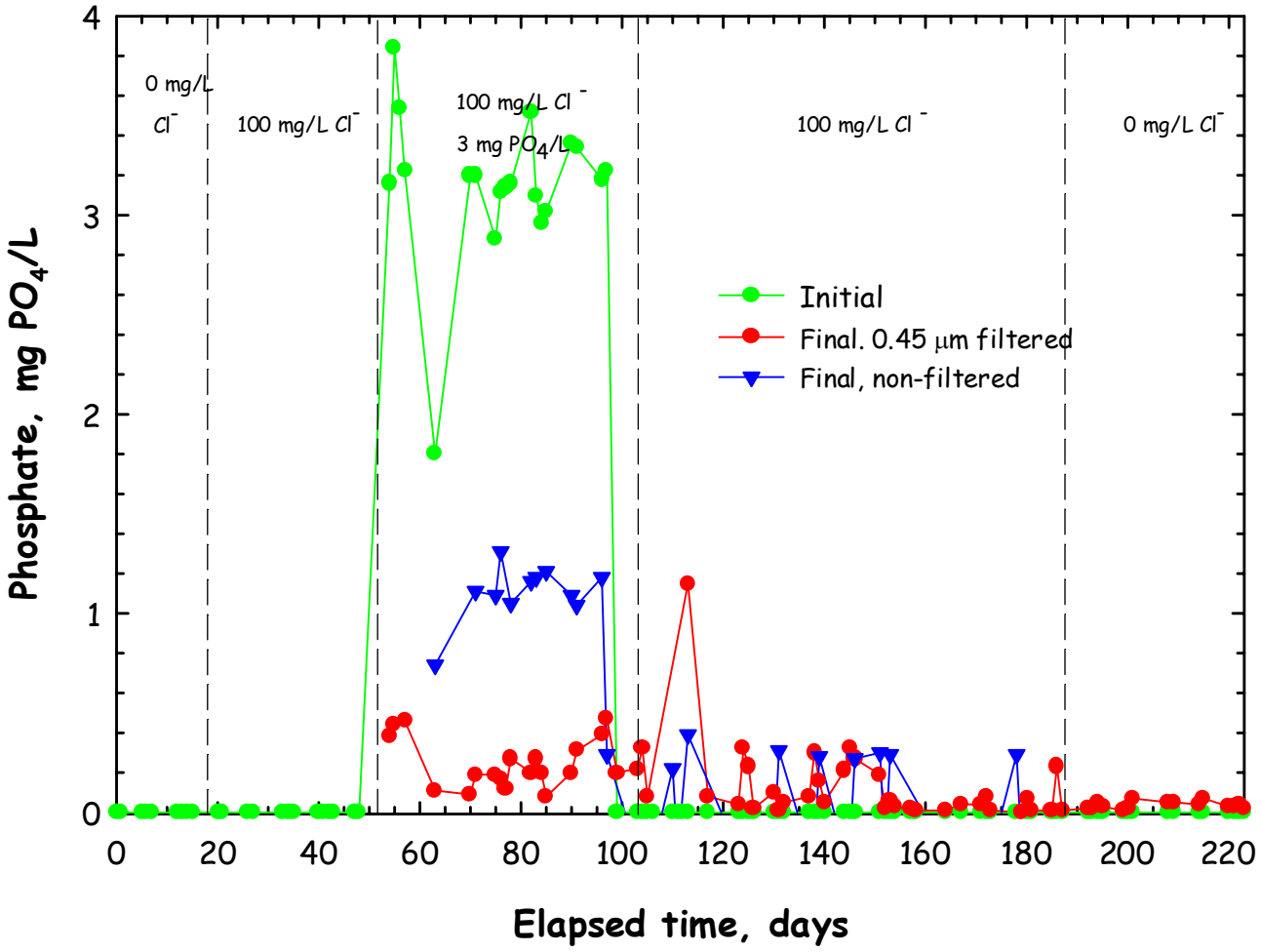
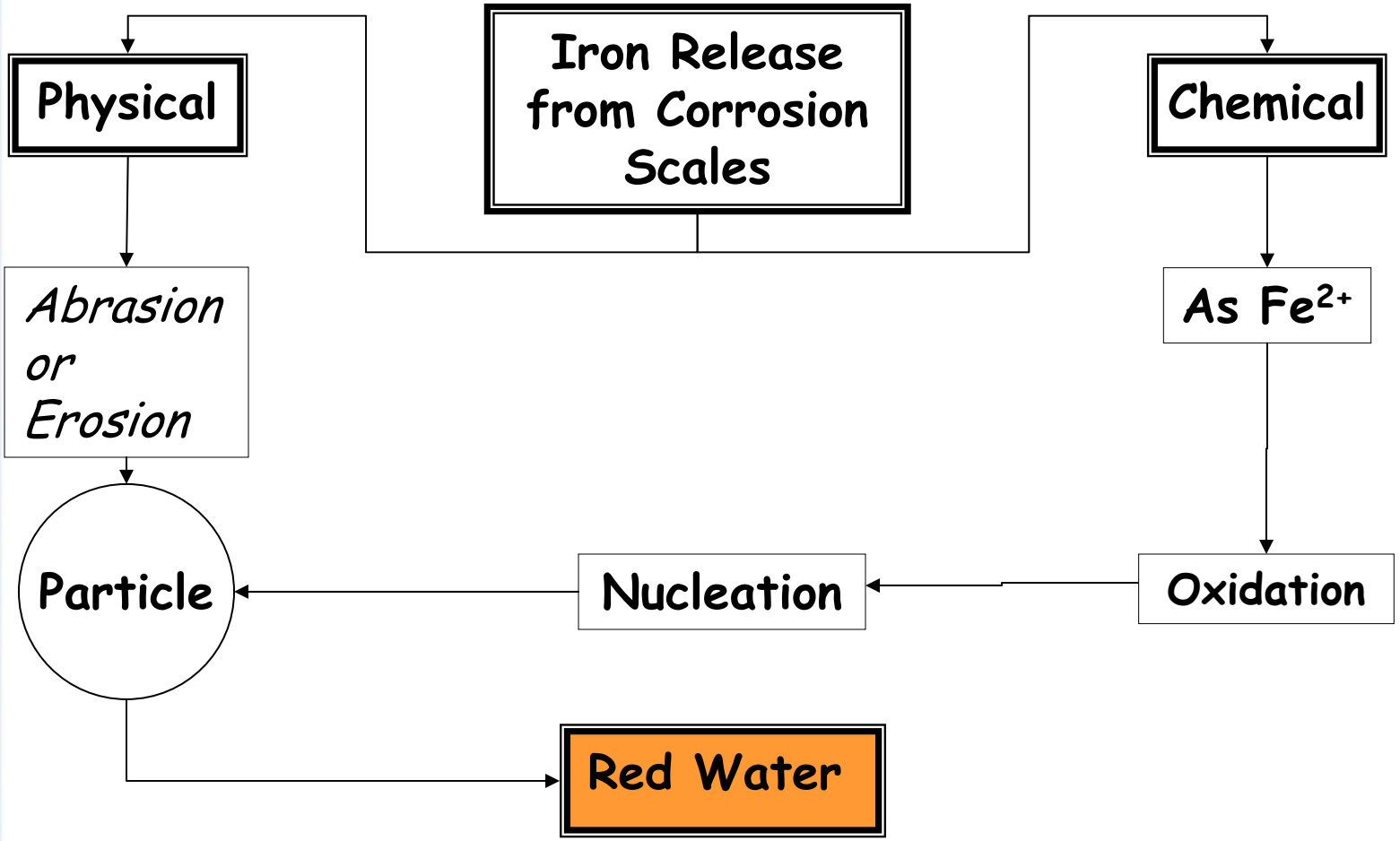
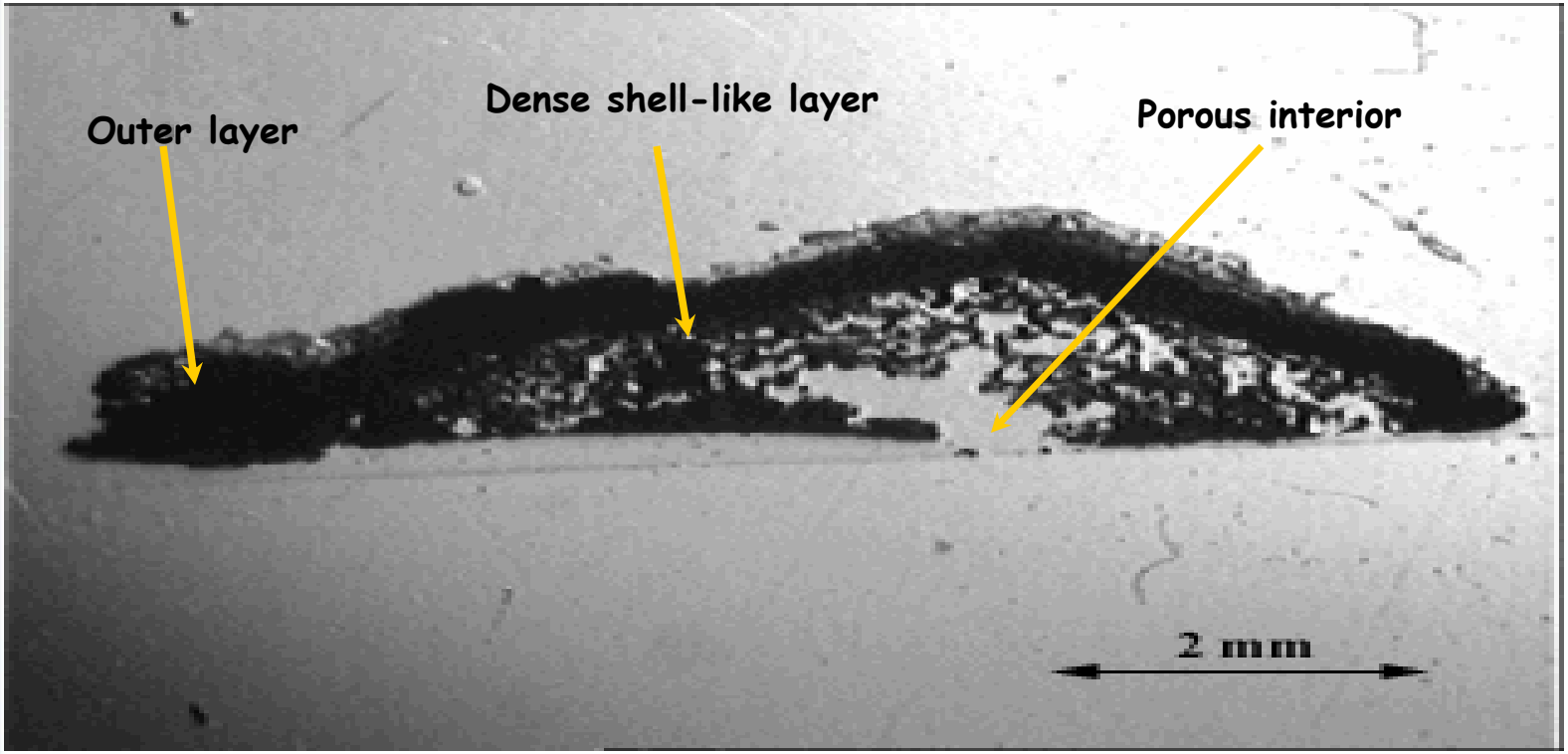
Phosphate Demand/Release



"Red Water" Formation



Iron Pipe Scale Structure

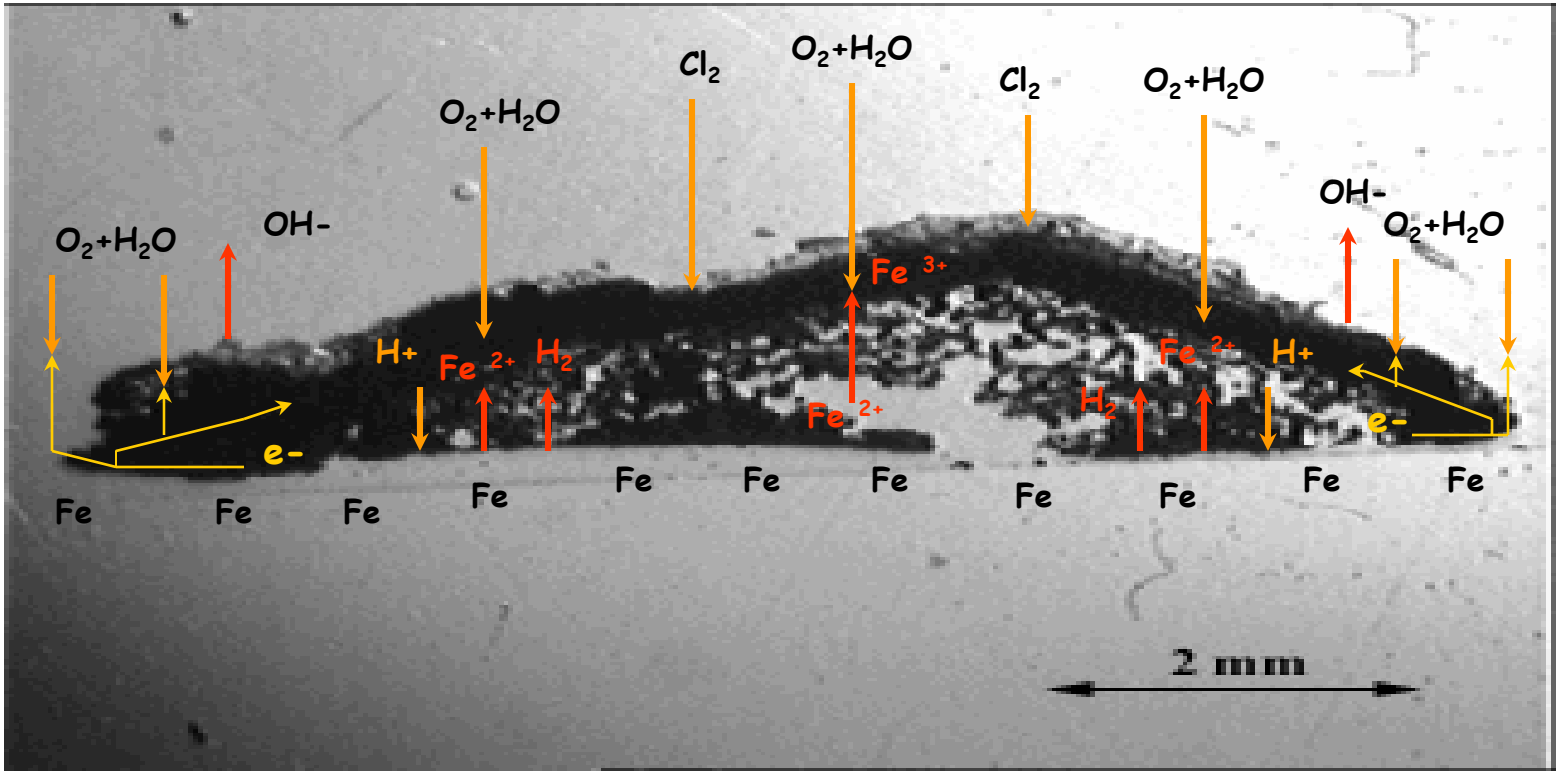


Outer Layer- relatively thin, comprised of Fe (III) compounds

Shell-like Layer- relatively dense, thin, primarily Fe_3O_4 and geothite, conductive

Porous Interior- mostly Fe (II) compounds, porous, reservoir of Fe2+, attracts anions to maintain electroneutrality

Electron Transfer/ Redox Couples/Fe(II) Generation



$Fe(s) + 2H^+ \longrightarrow Fe^{2+} + H_2(g)$

$Fe(s) + 2FeOOH(s) + 2H^+ \longrightarrow 3Fe^{2+} + 4OH^-$ (Kuch mechanism)

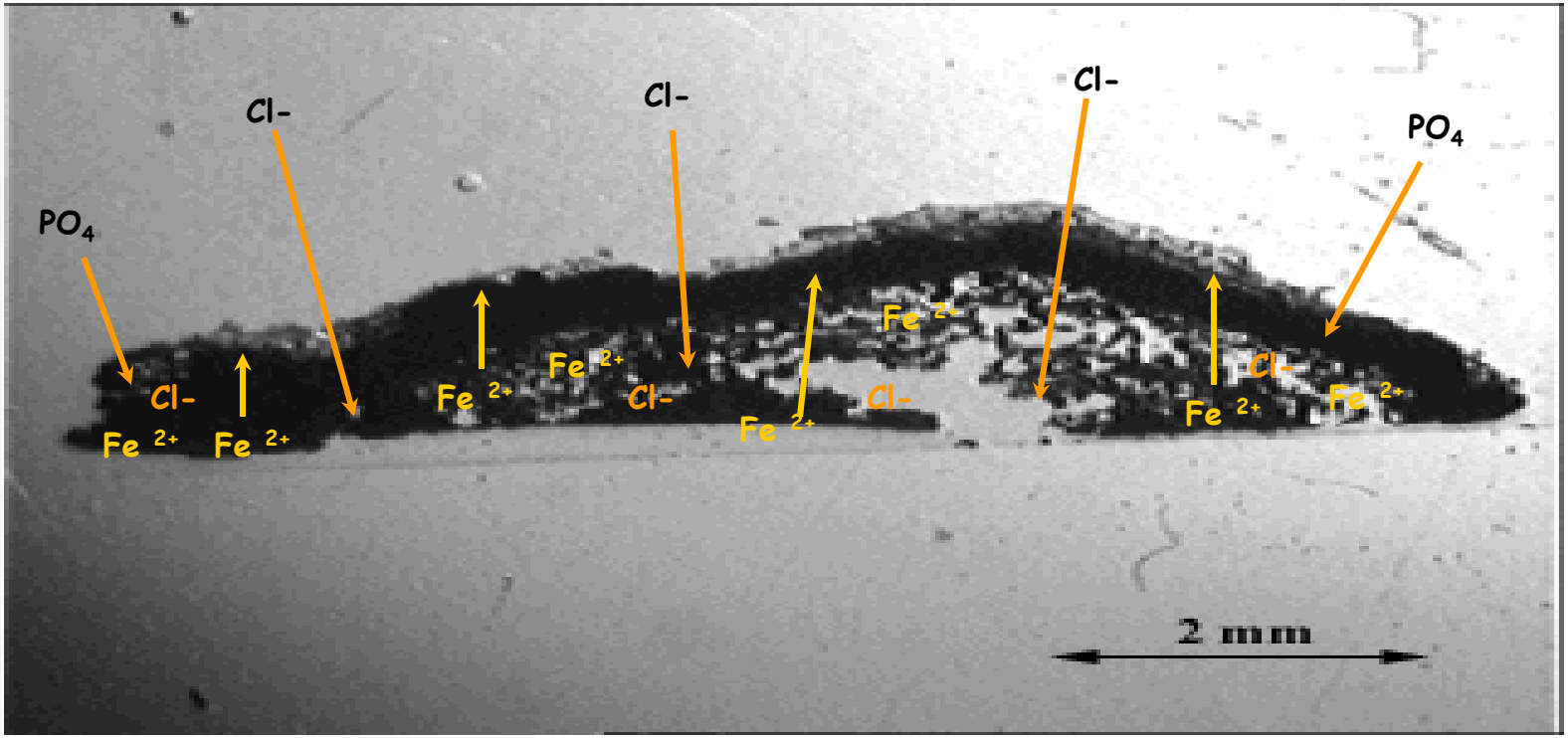
$O_2(g) + 4Fe^{2+} + 2H_2O \longrightarrow 4Fe^{3+} + 4OH^-$

$HOCl + 2Fe^{2+} + H_2O \longrightarrow 2Fe^{3+} + Cl^- + OH^-$

-Dissolution of Fe(II) solids in porous interior

-Reductive dissolution of Fe(III) solids/microorganisms

Role of Chloride and Phosphate



$Fe^{2+} + 2H_2O + Cl^- \longrightarrow Fe(OH)_2(s) + 2HCl$ - accelerate corrosion, electroneutrality

$3Fe^{2+} + 2PO_4^{3-} \longrightarrow Fe_3(PO_4)_2(s)$ – solubility

$Fe^{3+} + PO_4^{3-} \longrightarrow FePO_4(s)$ – solubility

$Fe^{3+} + OH^- + PO_4^{3-} \longrightarrow FeOOH\text{-}PO_4$ particle – porosity, reductive dissolution, Kuch mechanism

Conclusions

- Chloride rapidly enhanced the release of iron
- Orthophosphate reduced iron release of iron
- Orthophosphate also reduced color and turbidity
- Iron pipe section has a large oxidant demand
- Iron pipe consumes orthophosphate